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(54) Well instrument telemetry

(57) Data is transmitted from an instrument 22 within a well 11 during drilling by provision in the drill string 12 of a clutch 23 which is operable by data signals from the instrument between a condition in which power is transmitted from a driving motor 17 to a bit 14 at the lower end of the string and a released condition interrupting the drive to the bit, with the data being transmitted to the surface through the drill string 12 in the form of changes in torque in the string as a result of the changes in the drive to the bit 14, and with means 70, 71 being provided at the surface for response to the alterations in torque in the string to produce an output representative of the transmitted data.

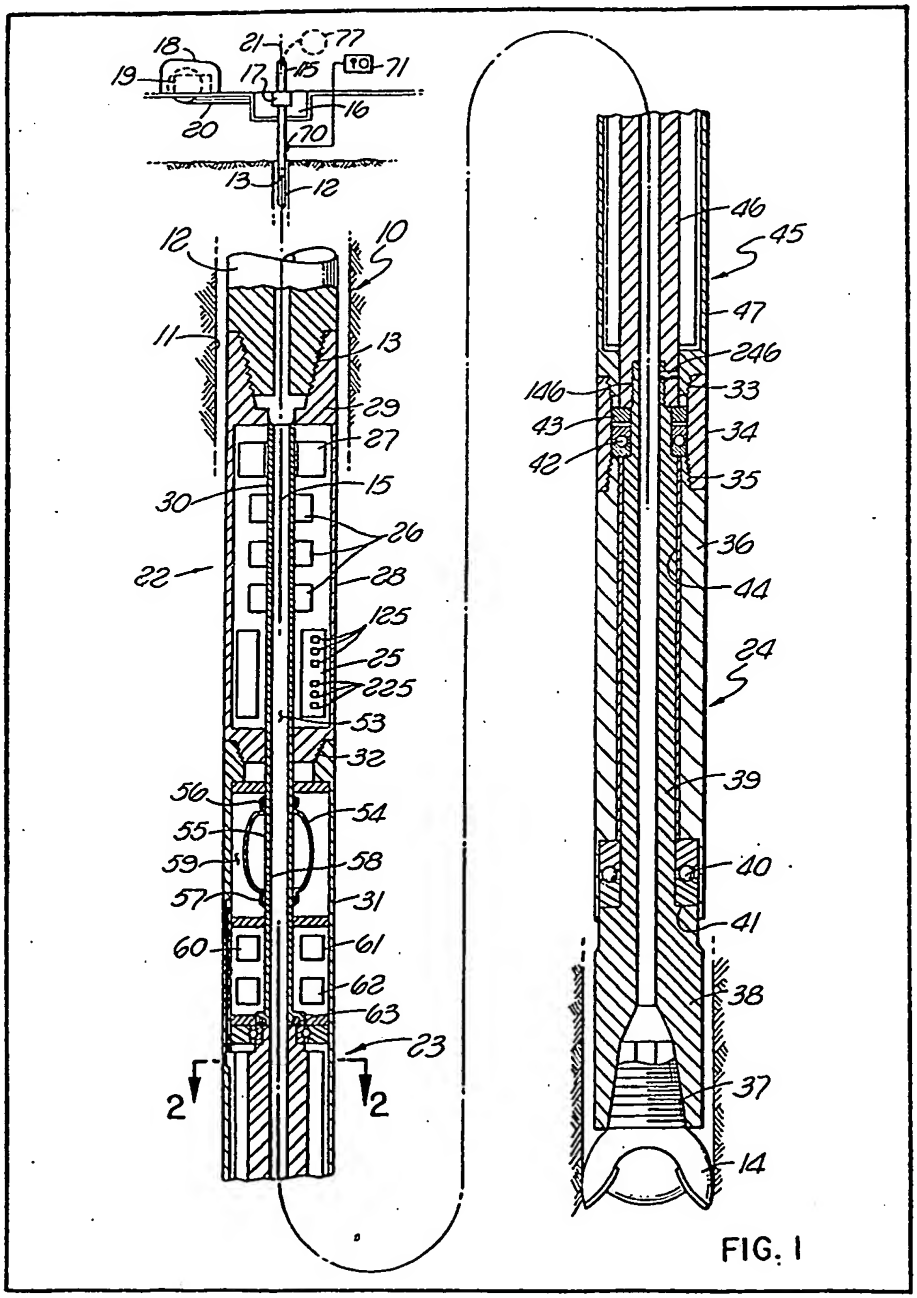

FIG. 1

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SPECIFICATION

Well instrument telemetry

Background of the invention

This invention relates to improved apparatus and methods for transmitting data from an instrument within a well to the surface of the earth.

In using many types of well instruments, such as steering or surveying tools. it is often desirable to transmit sensed data from the instrument to the surface of the earth while the instrument remains in the well, and preferably in many instances during an acutal drilling operation. A conventional way of delivering data signals to the surface has been by electrical transmission through a wire line used to suspend the instrument in the well and to lower it into and withdraw it upwardly from the well. Such use of a wire line for the purpose is expensive and time consuming in that it usually necessitates complete removal of the instrument and line from the well each time that a section of pipe is added to or removed from the string. In order to avoid the use of a wire line, telemetry systems have been proposed which utilize changes in pressure of the circulating mud for transmitting information from a down hole location to the surface of the earth, by inducing such changes in correspondence with information sensed by the instrument and then responding to those pressure changes at the surface.

Summary of the invention

The major purpose of the present invention is to provide an improved arrangement for transmitting information from a well instrument to a surface location without the necessity for a wire line or for removal of the instrument from the well upon each change in length of the drill string, and without the necessity for provision of valves in the mud system or other means for changing the pressure or flow characteristics of the circulating mud in correspondence with the data being transmitted. The telemetry system of the invention enables transmission of signals during an actual drilling operation and in a manner delivering data to the surface very effectively and positively and essentially simultaneously with the development of that data by the down hole instrument. If the instrument is a steering tool, an operator can thus be apprised of the actual inclination of the well bore and the azimuth of that inclination while the bit is being driven rotatively, so that correction can be easily made from the surface to steer the bit and drill string in optimum fashion.

To attain these results, I provide in the drill string a clutch which is responsive to data signals from the steering tool or other controlling instrument, and is actuable by those signals between a driving condition in which power is transmitted to the bit and a released condition interupting the drive to the bit. These changes in corresponding alterations in the torque to which the drill string is subjected, and those changes in torque are sensed at the surface of the earth and utilized for producing a readout indication or other output representative of the down hole data. In certain forms of the invention, the clutch may be operatively interposed between the bit and a motor which drives the bit, while in another form of the invention the clutch may be connected into the string above a bit driving motor and act to interrupt the transmission of reactive torque from the motor to the portion of the string thereabove to in that way affect the drive to the bit.

The clutch is preferably a fluid pump having two sections which act upon relative rotation to pump a fluid along a predetermined path, with valve means being provided for interrupting the flow of fluid through the pump and thereby transforming it to a positive drive assembly in which the two sections of the pump are not relatively rotatable and the bit is therefore driven positively by the associated motor.

Brief description of the drawings

The above and other features and objects of the invention will be better understood from the following detailed description of the typical embodiments illustrated in the accompanying drawings, in which:

Fig. 1 is a partially diagrammatic vertical section through a well drilling string having a steering instrument and telemetry system embodying the invention;

Fig. 2 is an enlarged transverse section taken on line 2—2 of Fig. 1;

Fig. 3 is a diagrammatic representation of the hydraulic and electrical circuits of the invention;

Fig. 4 represents the data and torque pulses in Figs. 1 to 3 equipment;

Figs. 5 and 6 illustrate diagrammatically two variational forms of the invention, and

Fig. 7 is an enlarged sectional detail taken in the area encircled in Fig. 6 and identified by the number 7.

Description of the preferred embodiment

Fig. 1 illustrates a drill string 10 which is driven from the surface of the earth to drill a well bore 11. The string is formed in conventional manner of a series of drill pipe sections 12 connected together in end to end relation at threaded joints 13, and carrying at their lower end a bit 14 which acts by rotation to drill the hole. The upper section of the string is an externally non-circular kelly 115, which is driven rotatively by a rotary table 16 through a master bushing and kelly bushing assembly 17. The usual draw works 18 includes a motor 19 which acts through a drive 20 to turn the rotary table 16 and string 10 about the main vertical or longitudinal axis 21 of the well.

Near its lower end, the drill string includes an instrument section 22 which acts to control a clutch assembly 23 for making and breaking the drive connection between the upper portion of the string above instrument section 22 and the bit. A

bearing assembly 24 beneath the clutch assembly transmits axial and lateral forces from the bit to the side wall of the drill string.

Instrument section 22 may be a steering tool, survey instrument, or any other instrument capable of responding in some way to conditions in the well and producing data signals representing information to be transmitted to the surface of the earth. For the purposes of the present discussion, it is assumed that instrument 22 is a steering tool, having a sensing unit 25 which is capable of sensing the inclination of the longitudinal axis 15 of the drill string at the location of instrument 22 and the azimuth or compass direction of that inclination, for use by an operator in following the advancement of the drill string through the earth and the point to which the bit has advanced at a particular instant. For example, sensor 25 may be of the type shown and described in United States Patent No. 2,791,043 issued February 12, 1974 to Michael King Russell on "Indicating Instruments". The instruments shown in that patent have a plurality of gravity sensors operable to sense different components of the inclination of the instrument, and a plurality of magnetic compass units operable to sense different components of azimuth, together with electronic circuitry acting to produce a series of digital pulses in multiplexed fashion which in that prior invention were carried to the surface of the earth through an electrical cable and there combined to produce indications of the actual inclination of the instrument in the well, the direction of that inclination, and the angle to which the instrument is turned about its longitudinal axis.

In the apparatus of Fig. 1, sensor unit 25 may typically include two or more gravity component sensors 125 and two or more direction component sensors 225 as in the above discussed prior patent, with the information from these sensors being delivered to electronic units 26 which are energized by an appropriate battery or batteries 27 and produce an output as in the prior patent consisting of a series of multiplexed digital pulses representing the data to be transmitted to the surface of the earth. The information content of the data may be introduced into the data train by varying the timing between successive pulses in a recognizable pulse width coding pattern.

Sensor unit 25 and the electronic elements 26 and battery or batteries 27 may be contained within a pipe sub or section 28 which is threadedly connected at its upper end 29 to the next upper section 12 of the drill string, and which has a wall thickness great enough to transmit the drilling torque therethrough. An inner pipe or tube 20 may be carried within sub 28 and appropriately rigid secured thereto, with units 25, 26 and 27 being contained within the annular space between outer pipe section 28 and inner tube 30, and being appropriately connected to one or both of these parts in fixed relative position. The electronic units 26 and battery or batteries 27 are typically illustrated as annular and disposed about inner tube 30 and suitably secured thereto. Tube 30 may be sealed at its opposite ends to pipe section 28, to isolate the annular space about tube 30 from communication with the drilling mud which flows downwardly through the interior of the drill string and through tube 30 toward the bit.

Clutch assembly 23 includes an outer tubular body or pipe sub 31 whose upper end is threadedly connected at 32 to the lower end of instrument sub 28, and whose lower end is threadedly connected at 33 to a section 34 of bearing assembly 24. This section 34 of the bearing assembly is in turn threadedly connected at 35 to a section 36 of the bearing assembly. Bit 14 is threadedly connected at 37 to a bit carrier part 38 having a tubular shaft 39 which projects upwardly within the outer parts 34 and 36 of the bearing assembly and is journalled for rotation relative thereto about axis 15 of the drill string. Axial forces exerted upwardly against the bit may be transmitted to the main body of the drill string through a lower thrust bearing 40 interposed axially between the lower end of section 36 and a shoulder 41 in part 38. Axial forces in the opposite direction may be transmitted from the upper end of part 36 through a second thrust bearing 42 to a ring 43 carried about and secured rigidly to shaft 39 of the bit carrying part 38. Lateral forces exerted by the bit may be transmitted to part 36 by a sleeve bearing or bearings 44. It will of course be understood that other bearing arrangements may be substituted for the one typically illustrated.

Directly above the upper end of the bearing assembly 24, the clutch assembly includes a preferably vane type fluid pump 45, whose rotor 46 is connected rigidly to and drive shaft 39 and the connected bit 14, and whose stator or outer tubular body 47 is typically and somewhat diagrammatically illustrated as constituting a portion of the previously mentioned outer tubular body 31 of clutch assembly 23. It will of course be understood that the pump may if desired be formed separately from and secured appropriately to the remainder of clutch assembly 23. The connection between elements 39 and 46 may be made by provision of interengaging threads 146 of the parts and a pin or pins 246 retaining the threadedly interconnected parts against relative rotation.

Fig. 2 illustrates one form which the pump 45 may taken in which rotor 46 carries a series of circularly spaced radially extending vanes 48 and rotates about the main longitudinal axis 15 of the tool relative to outer body 47 and within a cylindrical chamber 49 which is eccentric with respect to axis 15 so that the vanes can move slidably inwardly and outwardly relative to the rotor as the rotor turns to provide chamber 50 between the vanes first progressively increasing and the progressively decreasing in size in a manner pumping fluid from an inlet passage 51 in body 47 to an outlet passage 52 formed in the opposite side of that body. Pump 45 is thus of the

positive displacement type, and the fluid which flows therethrough is a liquid which will act when the discharge of fluid from the exhaust passage 52 is blocked to positively lock the rotor of the pump against rotation relative to the outer stator element 47. Circulating mud flow downwardly through a central passage 53 in the pump toward the bit, with the fluid which is conducted through the pump chambers 50 being isolated at all points from contact with the mud. the mud thus cannot under any circumstances contact the outside of the rotor 46 or vanes 48 or any of the other parts forming the closed circulation path for the hydraulic fluid pumped by unit 45, to thus prevent deterioration of any of those moving parts by the mud.

Above vane pump 45, clutch assembly 23 contains an annular bellows or other equivalent element 54, for communicating the pressure of the circulating mud to the hydraulic fluid handled by pump 45 in order to maintain the two fluids at essentially corresponding pressures and prevent unwanted leakage between one fluid and the other. Bellows 54 may preferably be received about a lower tubular extension 55 of the tube 30 of the instrument 22, and be annularly sealed to that extension at the upper and lower ends 56 and 57 of the bellows, with one or more apertures 58 in extension 55 communicating the pressure of the circulating mud through the side wall of tube 55 to the interior of the bellows. The chamber 59 formed in body 31 about bellows 54 contains a quantity of the hydraulic circulating fluid which flows through the pump, and acts as a supply reservoir maintained under the pressure of the circulating mud. Below bellows 54, body 31 may contain a relief valve 60, a solenoid valve 61, and a pressure gauge element or pressure transducer 62. The lower extremity of the inner tube or element 55 is suitably sealed annularly with respect to the relatively rotatable inner tube 46 of fluid pump 45, as by an O-ring 63.

As seen in Fig. 3, pump 45 discharges through passage 52 to solenoid valve 61, which when opened allows fluid to bypass through a line 64 and inlet passage 51 back to the inlet side of the pump. When solenoid valve 61 is closed, hydraulic fluid cannot thus return to the inlet side of the pump, and consequently the rotor of the pump is locked against rotation relative to its stator, unless the discharge pressure from the pump reaches a predetermined excessive pressure for which relief valve 60 is set. Transducer 62 senses the discharge pressure in line 52 from the pump, and produces an electrical output representing that pressure in line 65 leading to electronic unit 26. This pressure signal and the inclination and azimuth signals from sensor 25 are delivered as appropriately multiplexed electrical pulses through line 66 to the solenoid 67 of valve 61, to open that normally closed valve each time that a pulse is received, and thus permit rotation of the rotor of pump 45 relative to its stator in correspondence with the [illegible]

The upper portion of Fig. 4 represents at 68 the electrical pulses which are delivered through line 66 from unit 26 to solenoid valve 61. As previously mentioned, the elapsed time between successive pulses corresponds to the different bits of information which have been derived from units 25 and 62 and are to be transmitted to the surface of the earth. The lower portion of fig. 4 illustrates at 69 the manner in which the drilling torque applied to bit 14 through the drill string from motor 19 at the surface of the earth decreases each time valve 61 is opened to break the drive through the drill string to the bit. The torque pulse train represented in the lower portion of Fig. 4 is conveyed upwardly to the surface of the earth through the side wall of the drill string, and is sensed by an element 70 at the surface of the earth for actuating a readout unit 71 in correspondence with the transmitted data. Unit 70 may be an accelerometer or strain gauge capable of sensing when and to what extent the metal of the side wall of kelly 15 or another section of the drill string is under torque, and producing an electrical signal in a line 72 leading to readout unit 71. In correspondence with prior Patent No. 3,791,043, readout unit 71 is capable of converting the multiplexed signals in line 72 to indications of the instrument inclination, azimuth, components of the inclination or azimuth, high side angle, or any other information sensed by the down hole instrument. The pressure sensed by unit 62 and communicated to the surface of the earth may be converted by readout unit 71 to an indication of the torque which is actually applied by the drill string to bit 14 at any instant during drilling.

To recapitulate briefly a cycle of use of the tool of Figs. 1 to 3, assume that the drill string is in the well as illustrated in Fig. 1, and that circulating fluid is being pumped downwardly through the interior of the string by a mud pump 77 to exit at the bit and flow upwardly within the annulus about the string. Motor 19 is energized to turn rotary table 16 and the drill string, with solenoid valve 61 being closed during most of the drilling operation to prevent bypassing of hydraulic fluid from the discharge side of pump 45 to its inlet side to thus lock the rotor of the pump against rotation relative to its outer body or stator and transmit rotation from the drill string directly through the pump to bit 14. When it is desired to transmit information from instrument sensing unit 25 and/or pressure transducer 62 to the surface of the earth, the electronic circuitry 26 is switched on in any appropriate manner, as by a pre-set timer or other switching means, and acts to deliver voltage pulses to solenoid 67 representing the data to be transmitted, and to intermittently open valve 61 in correspondence with that data. Each time valve 61 opens, the rotor of pump 45 is free to turn relative to its stator, and the transmission of power to bit 14 is thus interrupted, with result that the torque in the drill string above pump 45 decreases substantially to zero. This train of torque pulses are sensed at the

surface of the earth as discussed and used to actuate readout unit 71 to produce surface representations of the down hole data.

The variational arrangement illustrated in Fig. 5 is one in which the main upper portion of the drill string 10a does not rotate, but instead the bit 14a is driven relative to that upper portion of the drill string by a conventional down hole motor 19a typically operated by the pressure of the circulating mud. The bearing assembly 24a of Fig. 5 may be the same as assembly 24 of Fig. 1, and the clutch assembly 23a may similarly be the same as assembly 23 of Fig. 1. in Fig. 5, the stator or outer case 78 of motor 19a is connected at its upper end to a bent sub 73, which acts to direct the lower drilling assembly along a laterally deflected path to drill a directional hole. The lower end of rotor 79 of the motor is connected rigidly to the outer section of clutch assembly 23a (corresponding to outer body 31—47 of Fig. 1), which in turn is connected rigidly to the outer section of bearing assembly 24a (part 36 of Fig. 1). The inner rotating section of clutch assembly 23a (corresponding to rotor 46 of Fig. 1) is connected to the drill bit.

An instrument section 22a corresponding to section 22 of Fig. 1 may be connected into the string above bent sub 73, with wires extending downwardly through the bent sub to the motor and clutch assembly as part of a hydraulic and electrical circuit corresponding to that illustrated in Fig. 3. The upper end of the drill string in Fig. 5 may be retained against rotation by a unit represented at 74, with the torque in the drill string being sensed by an accelerometer or strain gauge 70a to produce electrical pulses in a line 72a which are converted within readout unit 71a to indications of the sensed down hole data.

In operation of the Fig. 5 apparatus, inclination and direction information sensed by instrument 22a is utilized to intermittently open and close the drive through clutch 23a between motor 19a and bit 14a. During intervals when the motor is driving bit 14a through clutch 23a, a substantial reactive torque is developed in the drill string above motor 19a, and when clutch 23 opens to break the drive to the bit that reactive torque reduces to or toward zero to produce intermittent decreased torque pulses in the drill string about the motor for readout by unit 71a.

Figs. 6 and 7 show another variational arrangement which may be essentially the same as that of Fig. 5 except that the clutch 23b is connected into the string 10b above the location of motor 19b rather than beneath that motor. In this case, motor 19b acts to drive bit 14b rotatively through a bearing assembly 24b corresponding to assemblies 24 and 24a of the first two forms of the invention. Motor 19b may be a conventional mud motor, having its rotor 119 connected to the driving shaft of bit 14b (corresponding to shaft 39 of Fig. 1), and having its stator 219 connected to the outer housing of bearing assembly 24b (corresponding to elements 39 and 36 of Fig. 1). The stator 219 of motor unit 19b is connected rigidly at its upper end to that rotor 46a of clutch assembly 23b (rotor 46 of Fig. 1), as by providing the stator 219 with an upwardly projecting cyclindrical shaft portion 80 connected threadedly to shaft 46b at 81 and keyed thereto by a pin 82. Axial forces may be transmitted from the outer housing or tube 31b of clutch section 23b to the stator of motor 19b by a thrust bearing or bearings represented at 83, and lateral forces may be transmitted by a bushing or other radial bearing structure represented at 84.

Stator 31b of the clutch assembly (corresponding to outer body 31 of Fig. 1 is connected at its upper end to bent sub 76 and through that sub with the remainder of the upper portion of the drill string. A unit 74b retains the upper end of the drill string against rotation, and a strain gauge or accelerometer or other sensing element 70b senses changes in the torque of the drill string and delivers electrical signals corresponding thereto to readout unit 71b which produces indications of the down hole data sensed by instrument 22b. Instrument 22b and the elements of clutch assembly 23b are connected into a hydraulic electric circuit corresponding to that illustrated in Fig. 3 to transmit torque pulses to the drill string in a manner corresponding to that discussed in connection with the first form of the invention.

In using the apparatus of Fig. 6, when clutch assembly 23b is in its locked direct drive condition, motor 19b acts to drive bit 14b rotatively to drill a directional hole along path determined by bent sub 76. The clutch in its locked condition transmits reactive torque upwardly to the bent sub and through that sub to the drill string for sensing by element 70b at the surface of the earth. When the clutch is released by actuation of a solenoid valve corresponding to that illustrated at 61 in Fig. 3, the rotor 46b of the clutch pump (corresponding to pump 45 of Fig. 3) is free to run relative to the stator of the pump, and by virtue of the connection of the rotor to the outer housing of motor 19b that housing is then free to rotate relative to the upper portion of the drill string, turning the outer tubular body of bearing assembly 24b relative to the bit and permitting the bit to remain stationary. The drive to the bit is thus broken, and the reactive torque from the motor to the upper portion of the drill string is interrupted in correspondence with the data signals received by clutch 23b. This variation in reactive torque in the drill string is sensed by element 70b and read out by unit 71b.

In other variational arrangements, it is contemplated that the control clutch assembly 23 23a or 23b, instead of breaking the drive to the bit completely in the released condition of the clutch, may only partially break that drive, by permitting a predetermined control slippage of the clutch causing transmission of power from the motor to the bit at a torque which is reduced in value but not to zero. For this purpose, the valve 61 may in that condition act when opened to pass enough fluid to permit some rotation of the rotor

of pump 45 relative to its stator while transmitting some torque therebetween and thus applying the desired reduced torque to the bit. The surface equipment can then be designed to respond to that reduction in torque.

While certain specific embodiments of the present invention have been disclosed as typical, the invention is of course not limited to these particular forms, but rather is applicable broadly to all such variations as fall within the scope of the appended claims.

Claims

1. Apparatus for use with a drill string having a bit at its end driven rotatively by a motor to drill a well in a relation developing torque in the string when the bit is being turned, said apparatus comprising:

an instrument carried by the string within the well and operable to develop signals representing data to be transmitted to the surface;

a clutch carried by the string and responsive to said signals for actuation, in a pattern representative of said data, between a first condition in which said motor is effective to drive the bit and a second condition at least partially releasing the drive to the bit; and

means responsive to changes in torque in the drill string resulting from said actuation of the clutch between said first and second conditions to produce an output dependent upon said data.

2. Apparatus as recited in claim 1, in which said clutch is connected into the drive between said motor and said bit and acts to at least partially release the drive between the motor and bit in said released condition of the clutch.

3. Apparatus as recited in claim 1, in which said motor is connected into said string at a location within the well, and said clutch is connected operatively between said motor and a portion of the string which is between the motor and the surface of the earth, said clutch acting in said released condition to at least partially interrupt the transmission of a reactive torque from the motor to said portion of the string.

4. Apparatus as recited in claim 1, in which said clutch includes a pump having two sections operable by relative rotation to pump a fluid and means responsive to said signals to control the flow of fluid through said pump in a manner regulating the relative rotation of said sections in correspondence with the data signals.

5. Apparatus as recited in claim 1, in which said clutch is a positive displacement pump having two sections operable by relative rotation to pump a fluid, and a valve responsive to said signals to control the discharge of fluid from said pump and thereby regulate relative rotation of the pump sections in correspondence with said data.

6. Apparatus as recited in claim 1, in which said clutch includes a pump having two sections operable by relative rotation to pump a fluid and means for preventing the flow of fluid through said pump to thereby prevent relative rotation of the sections and actuate the clutch to said first driving condition, and means for sensing the pressure of said fluid as an indication of the torque applied to said bit.

7. Apparatus as recited in claim 1, in which said clutch includes a pump having two sections operable by relative rotation to pump a fluid and means for preventing the flow of fluid through said pump to thereby prevent relative rotation of the sections and actuate the clutch to said first driving condition, and means for sensing the pressure of said fluid as an indication of the torque applied to said bit, said apparatus including means responsive to said pressure sensing means for delivering signals representative of sensed pressure to said clutch as part of the data to which the clutch is responsive and which is represented in the changes in torque in the drill string from which said output is produced.

8. Apparatus as recited in claim 1, in which said clutch includes a pump operable upon relative rotation of two elements to pump a fluid, and means responsive to said signals to control the flow of fluid through said pump to actuate it between said two conditions thereof, there being relief valve means operable upon attainment of a predetermined pressure at said pump to by-pass fluid from the discharge side of said pump and permit relative rotation of said elements in a manner limiting the torque applied to said bit.

9. Apparatus as recited in claim 1, including said drill string, said bit, and said motor as elements of the claim.

10. Apparatus as recited in claim 1, in which said means responsive to changes in torque in the drill string include strain gauge means near the surface of the earth for sensing said changes in torque.

11. Apparatus for use with a drill string having a bit at its end and which is power driven rotatively from the surface of the earth to drill a well, said apparatus comprising:

an instrument carried by the string within the well and operable to develop signals representing data to be transmitted to the surface;

a clutch carried by the string and responsive to said signals for actuation, in a pattern representative of said data, between a driving condition in which the clutch transmits rotation from the string to said bit and a released condition permitting rotation of the string relative to the bit; and

means responsive to changes in torque in the drill string resulting from said actuation of the clutch between driving and released conditions to produce an output dependent upon said data.

12. Apparatus as recited in claim 11, in which said clutch includes a pump operable upon rotation of said string relative to said bit to pump fluid, and means for controlling the flow of fluid through said pump to actuate it between said driving and released conditions.

13. Apparatus as recited in claim 11, in which said clutch includes a positive displacement pump connected into the drive between said drill string

and said bit and operable to pump a fluid upon rotation of the drill string relative to the bit, and a valve responsive to said signals to open and close a bypass from the discharge side of said pump to its suction side to control actuation of the clutch between said driving and released conditions in a pattern representative of said data.

14. Apparatus as recited in claim 11, in which said clutch includes a pump operable upon rotation of said drill string relative to said clutch to pump fluid, and means for regulating the flow of fluid through said pump in correspondence with said signals, there being means responsive to the pressure developed by said pump as an indication of the torque applied to said bit.

15. Apparatus as recited in claim 11, in which said clutch includes a pump operable upon rotation of said drill string relative to said clutch to pump fluid, and means for regulating the flow of fluid through said pump in correspondence with said signals, there being means responsive to the pressure developed by said pump as an indication of the torque applied to said bit, said clutch being actuable between said driving and released conditions in correspondence with signals from said pressure sensing means to deliver pressure data through the drill string to said torque responsive means.

16. Apparatus for use with a drill string having a bit at its end and a motor near the bit for driving the bit rotatively relative to a portion of the string which extends between the motor and the surface of the earth; said apparatus comprising:

an instrument carried by the string within the well and operable to develop signals representing data to be transmitted to the surface;

a clutch interposed operatively between said motor and said bit and responsive to said signals for actuation, in a pattern representative of said data, between a driving condition in which the clutch transmits rotation from said motor to said bit and a released condition at least partially releasing the drive between said motor and said bit; and

means responsive to change in the torque in the drill string resulting from said actuation of the clutch between driving and released conditions to produce an output dependent upon said data.

17. Apparatus as recited in claim 16, in which said clutch is a pump operable upon rotation of a rotor of said motor relative to said bit to pump a fluid, and means for controlling the flow of fluid through said pump to actuate it between bit driving and released conditions.

18. Apparatus as recited in claim 16, in which said clutch includes a pump operable upon rotation of a rotor of said motor relative to said bit to pump a fluid, and a valve responsive to said signals to open and close a bypass from the discharge side of said pump to its suction side in a pattern representative of said data.

19. Apparatus as recited in claim 16, in which said clutch includes a pump operable by rotation of a rotor of said motor relative to said bit to pump a fluid, and means for controlling the discharge of fluid from said pump to actuate it between driving and released conditions, there being means reponsive to the pressure of said fluid developed by said pump as an indication of the torque applied to said bit.

20. Apparatus as recited in claim 16, in which said clutch includes a pump operable by rotation of a rotor of said motor relative to said bit to pump a fluid, and means for controlling the discharge of fluid from said pump to actuate it between driving and released conditions, there being a relief valve for relieving pressure at the discharge side of said pump beyond a predetermined value in order to limit the torque applied to said bit.

21. Apparatus for use with a drill string having a bit at its end and having a motor near the bit including a first section and a relatively rotating second section for driving the bit said apparatus comprising:

an instrument carried by the string within the well and operable to develop signals representing data to be transmitted to the surface;

a clutch interposed operatively between said first section of the motor and a portion of the drill string which is between said motor and the surface of the earth, said clutch being responsive to said signals for actuation, in a pattern representative of said data, between a first condition in which the clutch retains said first section of the motor against rotation relative to said portion of the drill string and a released condition permitting rotation of said first section of the motor relative to said portion of the drill string and thereby at least partially releasing the drive from the motor to the bit; and

means responsive to changes in torque in the drill string resulting from said actuation of the clutch between said first condition and said released condition to produce an output dependent upon said data.

22. Apparatus as recited in claim 21, in which said clutch includes a pump operable upon rotation of said first section of the motor relative to the drill string to pump a fluid, and means responsive to said signals to control the flow of fluid through the pump in correspondence therewith for actuation of the clutch between said first and released conditions.

23. Apparatus as recited in claim 21, in which said clutch includes a positive displacement pump operable upon rotation of said first section of the motor relative to said drill string to pump a fluid and a valve responsive to said signals to open and close a bypass from the discharge side of said pump to its suction side in correspondence with said signals.

24. Apparatus as recited in claim 21, in which said clutch includes a pump operable upon rotation of said first section of the motor relative to said portion of the drill string to pump a liquid, means for controlling the flow of fluid through said pump, and means for sensing the pressure produced by said pump and developing therefrom a signal indicative of the torque applied to said bit.

25. Apparatus as recited in claim 21, in which said clutch includes a pump operable by rotation of said first section of the motor relative to said portion of the drill string to pump a fluid, and means for controlling the flow of fluid through said pump in correspondence with said signals, there being relief valve means operable to relieve the pressure developed by said pump above a predetermined value to thereby limit the torque applied to said bit.

26. The method that comprises:

drilling a well bore using a bit carried at the end of a drill string and driven by a motor;

intermittently connecting two elements in said string against relative rotation and releasing said elements for relative rotation in correspondence with data to be transmitted to the surface of the earth and in a relation at least partially releasing the drive from said motor to said bit and thereby varying torque in the string in correspondence with said data; and

sensing variations in said torque in the string near the surface of the earth as an indication of said data.

27. The method as recited in claim 26, in which said bit is driven by rotating said string by said motor from the surface of the earth, and said two elements in the string are interposed operatively between the motor and said bit.

28. The method as recited in claim 26, including driving said bit rotatively with said motor located in the hole and with a portion of the string above the motor retained against rotation, said sensing of variations in torque in the string being effected by sensing changes in reactive torque in said non-rotating portion of the string above said motor.

29. The method as recited in claim 26, in which said motor is located in the well bore with a non-rotating portion of the string between the motor and the surface of the earth, and said two elements are intermittently connected and released at a location in the string between the motor and the surface of the earth.

30. An apparatus for transmitting data from an instrument disposed within a well substantially as described with reference to the accompanying drawings.

31. A method for sensing and transmitting signals indicative of variations of torque in a well string substantially as described in the examples disclosed herein.

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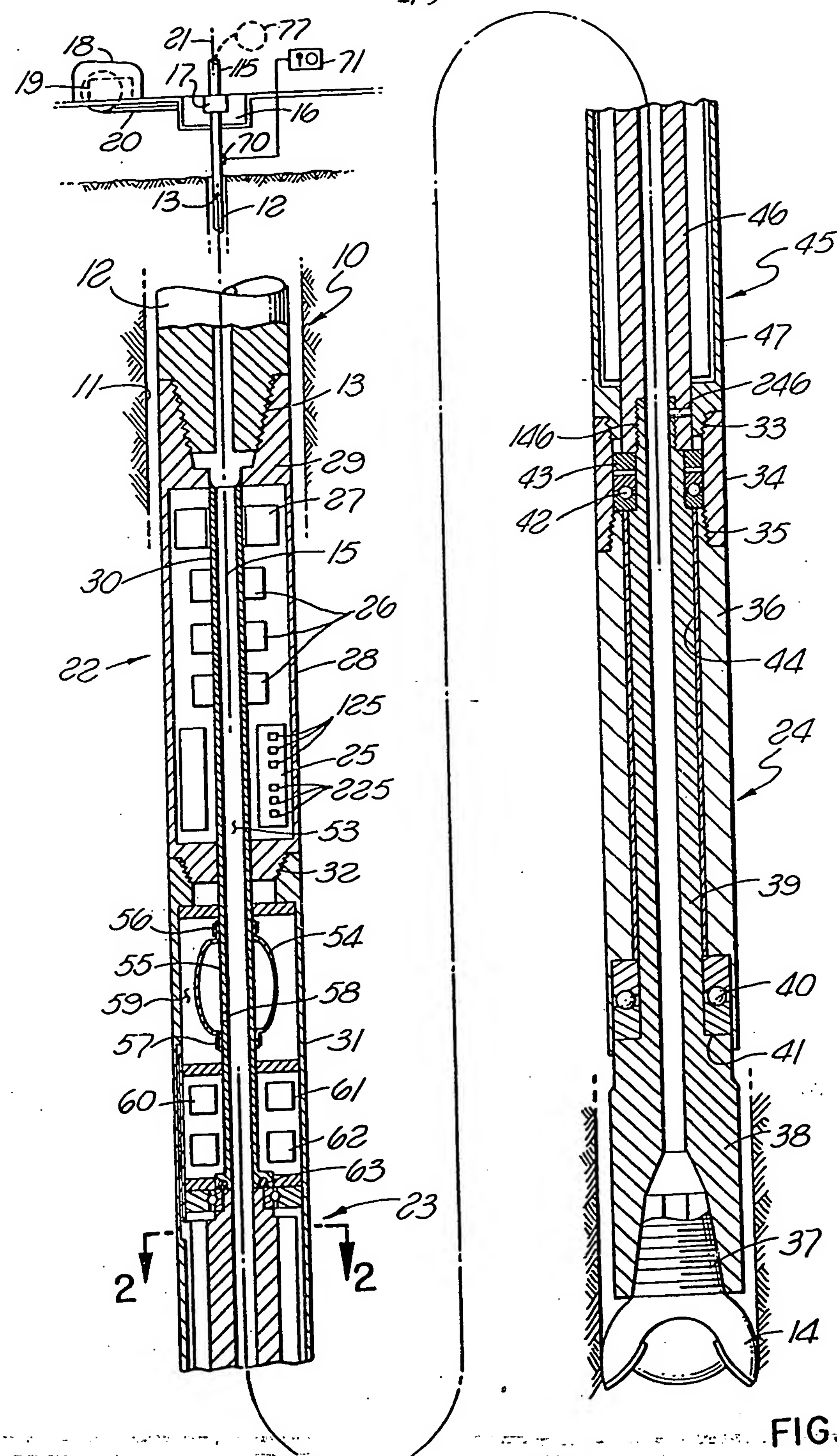

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FIG. I

FIG. 2

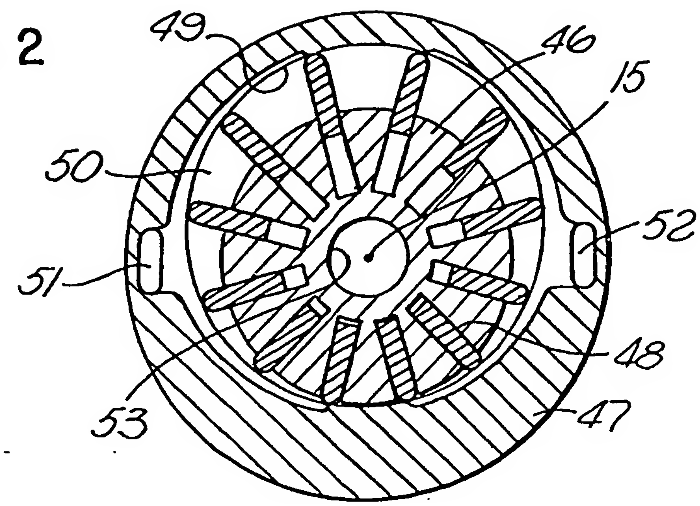

FIG. 3

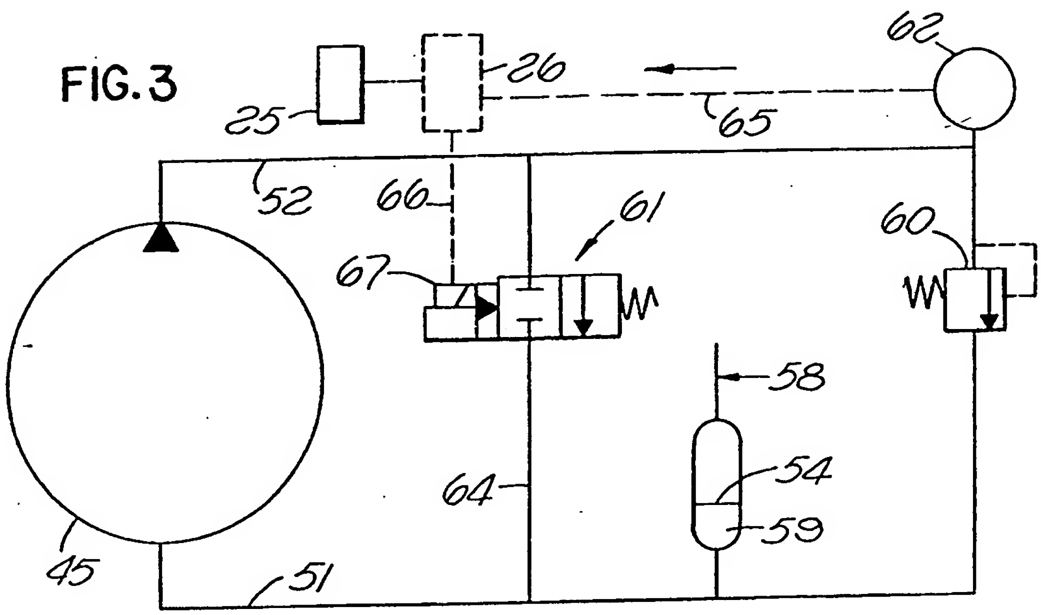

FIG. 4

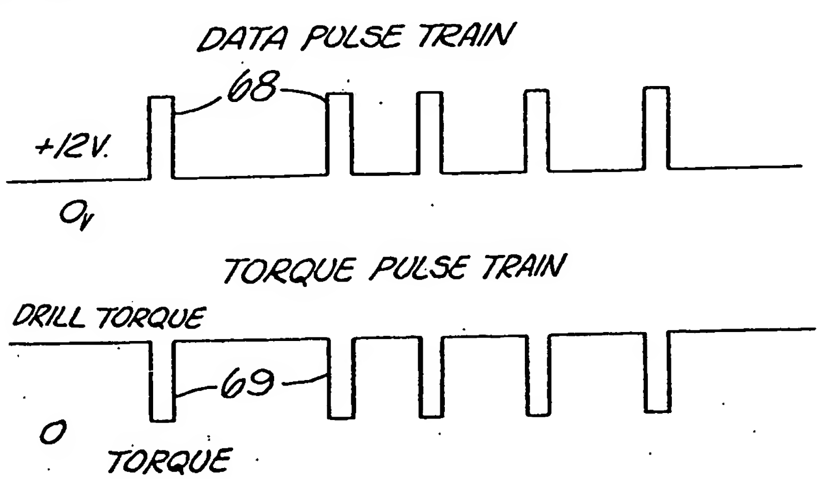

FIG. 5

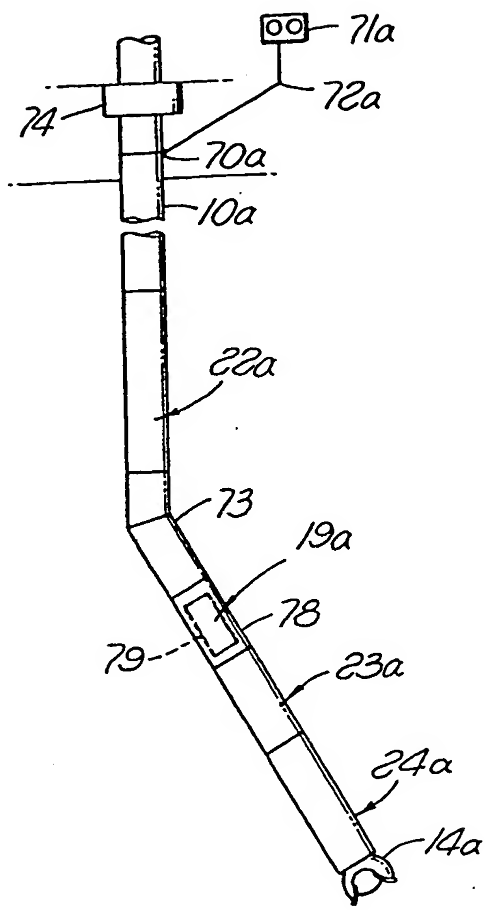

FIG. 6

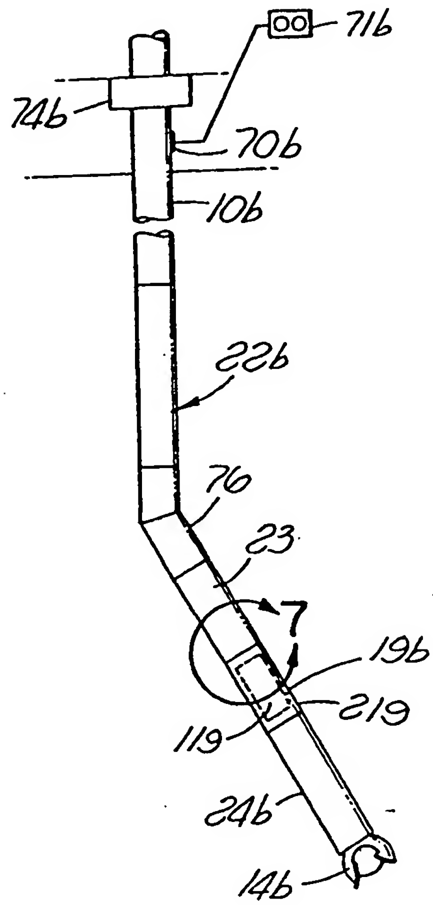

FIG. 7